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Elenco pubblicazioni e relativo abstract

1) *Modeling the spatial distribution and abundance of deep-water red shrimps in the Mediterranean Sea: a machine learning approach. Fisheries Research, 281, p.107257 (Catucci, E., Panzeri, D., Libralato, S., Cossarini, G., Garofalo, G., Maina, I., Kavadas, S., Quattrocchi, F., Cipriano, G., Carlucci, R. and Vitale, S., 2025)*

   Abstract: Spatially-explicit models are invaluable tools for analyzing the species-environment interactions, even at scales beyond that of direct observations. In fisheries context, the observations on species usually consist of data derived from survey campaigns, such as the Mediterranean International Bottom Trawl Surveys (MEDITS) programme. MEDITS survey foresees the use of a standardized protocol for data acquisition on demersal species, such as the blue and red shrimp *Aristeus antennatus* and the giant red shrimp *Aristaeomorpha foliacea*. These two species are recognized as highly valuable marked resources accounting for about 5 % of the trawl fishing income in the Mediterranean basin. Here, we developed a modeling framework for the analysis of the MEDITS data on those species. Within our modeling framework we aimed at detecting the existence of a divergence in the spatial patterns that could guide the definition of targeted management actions for those two valuable fishing resources. A Random Forest (RF) machine learning approach has been used to model both the occurrence (i.e., presence/absence) and the biomass index (kg/km2) of both species in four Geographical SubAreas (GSAs) located in the central part of the Mediterranean and the Ionian Sea. The RF showed high level of accuracy (i.e., K=0.83 and K=0.88, for *A. antennatus* and *A. foliacea*, respectively) in modeling species occurrence, and good level of performance (i.e., R2=0.63 and R2=0.74, respectively) in modeling their biomass index (kg/km2). The niche overlap and statistical analyses we performed on the models outputs revealed the existence of a significant divergence in the spatial patterns between these species. This provides crucial ecological knowledge for the definition of targeted (i.e., species-related) management actions. Afterwards, the models have been extrapolated at the spatial scale of the Mediterranean Sea based on an approach we defined, called hyperspace. The *hyperspace* approach, while showing technical and ecological soundness, was meant to guarantee the reliability of model predictions in unknown areas. It reduces the need for a proper interpretation of “what is beyond a predicted value”, offering a straightforward method for model extrapolation. Our effort aims to provide insights for prioritizing key areas in conservation strategies and marine spatial planning. It also represents an important contribution towards adopting an ecosystem-based approach to fishery resource management in the Mediterranean basin.

2) *Food web analysis shows an exacerbated dependence of zooplankton on detritus in oligotrophic systems due to ocean warming. Progress in Oceanography, 231,*

p.103389 (Russo, L., Loschi, M., Bellardini, D., Congestri, R., Lomas, M.W., Libralato, S. and D'Alelio, D., 2025)

Abstract: Ocean warming can affect plankton both directly, through altered metabolic activities, and indirectly, modifying the physical–chemical properties of the water column, with possible effects on ecosystem functioning. To evaluate the combined action of warming-related physiological responses and environmental changes on plankton functioning, we carried out a long-term analysis (from 1994 to 2019) of the Bermuda Atlantic Time-series Study (BATS) dataset where ocean warming and stratification have driven a decrease in the net primary production over the last decade. Using the time series of plankton observations, we assembled 1000 replicates of a food web model for each year. We observed that the total flow of matter through the model remained constant over time, despite the increased oligotrophication, due to global warming, after 2014. In fact, the plankton food web remained robust through re-modulated trophic interactions with an increased detritivory to herbivory ratio of the food web over time. However, it was problematic to re-establish the trophic connections of the food web broken by ocean warming, as remarked by the increased relative internal ascendency. Thanks to trophic plasticity, the reduced zooplankton dependence on herbivory was compensated by a significant increase in the reliance on carnivory and detritivores, highlighting the crucial role of trophic interactions in buffering significant environmental short-term changes.

3) *Visual servoing of an underwater robotics arm for automatic sorting of crustaceans. Smart Agricultural Technology, 12, 101168 (Picardi, G., Astolfi, A., Seemakurthy, K., Hurst, B., Piana, E., Bosilj, P., & Calisti, M., 2025)*

Abstract: Crustaceans aquaculture is a rapidly growing sector, and automatising specific tasks can contribute to increasing its economic return as well as its sustainability. In this paper, we present an autonomous robotic system for sorting crustaceans by size, applied to crayfish farming. The system was designed in close collaboration with a crayfish farming company following a systematic user-driven approach. It consists of a waterproof robotic arm with a custom caging gripper lodging a camera, and a vision system to detect crayfish and sort them by size. All aspects of system design are presented: from manipulator and gripper design and control, to the development of the vision system, and the system integration. The system is evaluated in a controlled laboratory environment using synthetic crayfish models, and in a tank with live crayfish on a farm. Our evaluation shows that the presented system is capable of recognizing and selecting crayfish based on their size, and safely entrapping them in the caging gripper without causing any damage.

4) *Modeling and modification of fin-ray effect grippers to improve their load capacity and grasp stability. Sensors and Actuators A: Physical, 116711 (Sofla, M. S., Golshanian, H., Sklar, E. I., & Calisti, M., 2025)*

Abstract: Fin-ray effect (FRE) grippers are very popular because they can passively adapt to different shapes and therefore grasp a variety of objects. To optimize them for different purposes, in-depth analysis of their deformations and internal forces is

required, which necessitates accurate mathematical models. This paper presents a modeling framework that improves upon existing approaches by representing all structural components of the FRE finger as Cosserat rods, capturing their continuum behavior. The static forward kinematics problem for these fingers is formulated as the solution to multiple Cosserat rod models with coupled boundary conditions, and the experimental investigations verified the accuracy of the proposed modeling method. Then, simulations were performed to investigate the effects of different design parameters on the grasp forces and conforming to the shape of objects. By defining new boundary conditions, the FRE fingers in simulation could apply more grasp forces and better envelop the objects. Thus, a new mounting adaptor was designed based on the proposed boundary conditions, and the experimental investigations revealed that the modified design could improve the load capacity by up to 150 % and provide more stable grasps for delicate objects in a wide range of shapes and sizes.

5) *Stiffness estimation of delicate objects using a soft haptic whisker. In 2025 IEEE 8th International Conference on Soft Robotics (RoboSoft) (pp. 1-6) IEEE (Sofla, M. S., Yilmaz, A., Cielniak, G., & Calisti, M., 2025 – April)*

   Abstract: Soft whiskers allow for haptic sensing without damaging or altering the object being tested, which is particularly advantageous in delicate environments. A novel method for stiffness estimation using a soft haptic whisker is proposed in this research. The whisker, fabricated from Thermoplastic Polyurethane (TPU), deforms upon contact with objects, allowing for non-invasive stiffness measurement. Utilizing force and moment readings at the whisker's base, the system calculates the object's stiffness based on shape deformations modeled using the Cosserat rod theory. Experimental validation was conducted on both flexible tree saplings in a lab and delicate plant structures, such as strawberry stalks and leaves, in a polytunnel. Results demonstrate that the soft whisker can measure stiffness without damaging the objects, offering up to 30 times lower contact forces compared to a rigid probe. This method provides a safe, efficient solution for interacting with sensitive environments, opening possibilities for its application in robotic manipulation of delicate items.

6) *Enhancing collaboration in uncertain environment: Multi-Agent Reinforcement Learning for underwater monitoring. Expert Systems with Applications, 277, 127256 (Luvisutto, A., Celani, A., Renda, F., Stefanini, C., & De Masi, G., 2025)*

   Abstract: Underwater monitoring is extremely complex due to the lack of a global localization system, limited communication and environmental factors such as turbidity and darkness that limit visibility, affecting control and situational awareness. Typically, monitoring relies on a single autonomous underwater vehicle (AUV) or a set of independent AUVs; techniques which are prone to failure as they rely only on onboard odometry and sensors, making missions vulnerable to malfunctions, damage, and noise.
   To address these challenges, we propose a Multi-Agent Reinforcement Learning (MARL) framework to enable cooperation among multiple AUVs, mitigating the limitations of the underwater environment. Our in-silico solution focuses on a group

of robots learning a strategy to follow a partially hidden underwater pipe without global localization, while dealing with environmental disturbances affecting sensors and actuators. The numerosity of the agents, and most importantly their collaboration, helps overcome underwater visibility constraints. By sharing relative position information of neighboring agents with respect to the pipe, navigation is improved. By introducing quantitative measures for pipe exploration, we show that cooperation significantly enhances system performance compared to independent agents. Emerging collaboration among robots allows the swarm to complete pipe inspections faster and more efficiently than non-cooperative baseline models of non-interacting agents, even under extremely reduced visibility scenarios. Moreover, single agents also benefit from cooperation, learning effective policies more quickly and covering a longer portion of the pipe. Finally, our model guarantees explainability. We analyze learned strategies and provide a visualization method that allows the interpretation of the learned policies.

7) *Zodiaq: an isotropic flagella-inspired soft underwater drone for safe marine exploration. Soft Robotics (Mathew, A. T., Feliu-Talegon, D., Abdullahi Adamu, Y., Ben Hmida, I., Armanini, C., Stefanini, C., ... & Renda, F., 2025)*

   Abstract: The inherent challenges of robotic underwater exploration, such as hydrodynamic effects, the complexity of dynamic coupling, and the necessity for sensitive interaction with marine life, call for the adoption of soft robotic approaches in marine exploration. To address this, we present a novel prototype, ZodiAq, a soft underwater drone inspired by prokaryotic bacterial flagella. ZodiAq's unique dodecahedral structure, equipped with 12 flagella-like arms, ensures design redundancy and compliance, ideal for navigating complex underwater terrains. The prototype features a central unit based on a Raspberry Pi, connected to a sensory system for inertial, depth, and vision detection, and an acoustic modem for communication. Combined with the implemented control law, it renders ZodiAq an intelligent system. This paper details the design and fabrication process of ZodiAq, highlighting design choices and prototype capabilities. Based on the strain-based modeling of Cosserat rods, we have developed a digital twin of the prototype within a simulation toolbox to ease analysis and control. To optimize its operation in dynamic aquatic conditions, a simplified model-based controller has been developed and implemented, facilitating intelligent and adaptive movement in the hydrodynamic environment. Extensive experimental demonstrations highlight the drone's potential, showcasing its design redundancy, embodied intelligence, crawling gait, and practical applications in diverse underwater settings. This research contributes significantly to the field of underwater soft robotics, offering a promising new avenue for safe, efficient, and environmentally conscious underwater exploration.

8) *Boundary Control Behaviors of Multiple Low-cost AUVs Using Acoustic Communication. IEEE Access (Tarnini, M., Iacoponi, S., Infanti, A., Stefanini, C., De Masi, G., & Renda, F., 2025)*

   Abstract: This study presents acoustic-based methods for the control of multiple autonomous underwater vehicles (AUVs). This study proposes two different models

for implementing boundary and path control on low-cost AUVs using acoustic communication and a single central acoustic beacon. Both models are based on the history of relative range and do not rely on the full knowledge of theAUVs states based on a centralized beacon system. Two methods are presented: the Range Variation-Based (RVB) model completely relies on range data obtained by acoustic modems, whereas the Heading Estimation-Based (HEB) model uses ranges and range rates to estimate the position of the central boundary beacon and perform assigned behaviors. The models are tested on two boundary control behaviors: Fencing and Milling. Fencing behavior ensures AUVs return within predefined boundaries, while Milling enables the AUVs to move cyclically on a predefined path around the beacon. Models are validated by successfully performing the boundary control behaviors in simulations, pool tests, including artificial underwater currents, and field tests conducted in the ocean. All tests were performed with fully autonomous platforms, and no external input or sensor was provided to the AUVs during validation. Quantitative and qualitative analyses are presented in the study, focusing on the effect and application of a multi-robot system.

9) *Development of a soft gripper for replicating human grasps in forest nursery tasks. Robotics and Autonomous Systems, 189, 104987 (Sofla, M. S., Golshanian, H., Sklar, E. I., & Calisti, M., 2025)*

   Abstract: This research aims to automate labour-intensive tasks in forest nurseries by developing a soft gripper that mimics human workers' grasps to perform the singulation and sorting of tree saplings. By analysing human workers and conducting experimental investigations, the required grasp types and grip forces were identified. The Fin Ray Effect (FRE) structure, noted for its adaptability to asymmetric shapes, was chosen as the gripper's basis. However, modifications were necessary to achieve the required power and pinch grasp types and to provide the desired grip forces. Simulation analysis explored various beam configurations and boundary conditions of FRE fingers, resulting in a proposed modified design. Experimental investigations confirmed that the proposed gripper effectively delivered required grasps and grip forces. The new design enabled three additional grasp types for FRE grippers and increased grip forces by over 200 %. This gripper design is suitable for industrial pick-and-place applications where precise pinching grasp and various power grasps with sufficient payload capacity are needed.

10) *Toward autonomous blackberry harvesting with a soft gripper and vision-controlled robotic arm. In 2025 IEEE 8th International Conference on Soft Robotics (RoboSoft) (pp. 1-8) IEEE (Dalla Torre, F. T., Faris, O., Johnson, P. H., & Calisti, M., 2025, April)*

    Abstract: Robotic harvesting has become a significant topic in recent years as it addresses labor shortages, reduces production costs, and enhances food quality. In this work we present a comprehensive framework for robotic blackberry harvesting. It employs a low-cost 6-DOF robotic arm paired with a soft inflatable gripper specifically designed for blackberries and it leverages the capabilities of YOLOv8 for vision-based control. A standardized set of metrics and tests to objectively evaluate the performance of robotic harvesting in controlled conditions and to

inform field deployment is introduced. Our system reached peak performances of 98.4% for the vision component and of 76.6% for grasping effectiveness, with a combined success rate of 52% for the whole pipeline, but with significant variability depending on the pose of the blackberry. The multipurpose arm showed significant limitations, suggesting the development of specialized hardware for future deployment. Our results demonstrate the system’s potential for robotic harvesting of blackberry, while suggesting areas for future research.

11) *Il Porto di Livorno, una realtà contemporanea grazie a TIM Enterprise. Le novità dal 2024 ad oggi*